HAZARD CONTROL PLAN
for
D-T NEUTRON GENERATOR OPERATION
IN THE NRAD CAVE (53-3N)

ID number:	LANSCE-3 HCP-19.0
initial risk:	**MEDIUM**
residual risk:	**LOW**
work permits required:	none
Location:	TA53-3N, 53-1270

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0. INDEX

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1. DESCRIPTION OF WORK

LANSCE-3 maintains and operates a commercial (MF Physics Model A-711 [1]) sealed-tube D-T neutron generator source in the (Neutron Radiography) NRAD cave, area 53-3N, with controls and data acquisition equipment in a co-located wood-frame shed, BLDG 53-1270. The output of this neutron generator is approximately 10^{11} 14-MeV neutrons/sec. Research activities scheduled to be conducted with this source include neutron radiography, materials irradiation, neutron activation analysis, and detector calibration. This document describes procedures and physical safeguards necessary to protect personnel from radiation, chemical, and electrical hazards associated with the routine operation of this source. This document is NOT intended to be a manual for operation and maintenance of the source. The manual supplied by the equipment manufacturer is to be used for those purposes.

2. DESCRIPTION OF THE SOURCE

The Model A-711 neutron generator consists of four separate units: a light-weight portable ion accelerator (the neutron generator 'head'), a pressurized tank containing the power supplies, a refrigeration-type cooling system, and a small control console.

The accelerator assembly, or head, consists of a sealed neutron-generating glass tube enclosed in a stainless steel housing. This housing is pressurized to 60 +/- 3 psi with an insulating gas, sulfur hexaflouride (SF_6), to allow application of the accelerating voltage. The accelerator head is connected to the power supply and cooling unit by long coaxial cables.

The neutron generating tube is a vacuum-tight, miniature ion accelerator which contains an ion source, two gas occlusion elements, a high voltage lens assembly, accelerating section, and a titanium tritide target. A closed-loop heat exchange system uses Vertrel XF [2] (decafluoropentane, a Freon 113 substitute) to cool the ion source, while a similar closed loop system using clean tap water cools the target assembly.

High voltage power supplies of the conventional full-wave voltage doubler type are contained in a cylindrical tank which is pressurized to 35 +/- 2 psi with SF_6. The accelerating power supply is rated at 200 kV dc maximum at 5 mA current; the ion source power supply is rated at 10 kV dc maximum at 20 mA current. The accelerating power supply consists of two sections, one of which is capable of generating voltages up to 150 kV, the other to 50 kV. The two sections are connected in series to provide a total accelerating potential of up to 200 kV. Each section consists of a step-up transformer, diode stacks, filter capacitors, and suitable surge-limiting resistors. The output voltage is sensed by measuring the current in a precision resistor string connected to the 200 kV terminal. The negative terminal of the accelerating power supply is at ground and connected to the target; the positive terminal is connected to the cathode of the ion source.

The cooling system, which is completely self-contained, consists of three major subsystems: a target cooling loop, a source cooling loop, and a refrigeration unit which exchanges the heat from these loops with the ambient air. The refrigeration unit circulates gaseous Freon 12 to maintain the temperature in the heat exchanger slightly above 32 deg F. With the exception of the coolant lines to the source and target, the components of all three subsystems are enclosed in the cooling unit cart. This caster-mounted assembly contains the commercial refrigeration unit, heat-exchanger tank, separate sumps and pumps for target and source cooling loops, and the necessary fittings. Since the system is completely enclosed, with all coolants recirculating, no drain or primary water source is required, and there is no radioactive waste generated by normal operation.

The system junction box and a panel of interlock-failure indicator lights are mounted on the cooling unit cabinet. This location is one of convenience rather than functional association with the refrigeration system. Cable connections for the entire system are made at the junction box. Also found on the junction box is the cooling unit on/off switch and an emergency kill switch that can de-energize the system and prevent neutron production.

The system console is a rack-mounted NIM-bin sized unit which contains all the controls and instrumentation necessary for completely remote operation of the A-711 neutron generator. The console is connected to the system junction box (located on the cooling cart) by a 50-ft cable. The console contains a key-operated main power switch, interlock status lights, meters and controls for the beam and source current and high voltage, and a switch for initiating neutron production.

3. HAZARDS

The hazards associated with the D-T neutron generator can be divided into three categories:

1. radiation
2. electrical
3. chemical

Radiation Hazards include prompt 14-MeV neutrons and x-rays and secondary neutron and gamma radiation while the source is operating. When the source is turned off, gamma and beta radiation from activated materials may be present. These activated materials include, among other things, the fluids used to cool the ion source (Vertrel XF) and target (water), the gas (SF_6) used to insulate the neutron head, and the iron in the collimation crypt surrounding the source. In addition, the source contains approximately 8 Ci of tritium in a sealed-tube ion-source and target assembly. This tritium is not a hazard unless the tube is damaged and leaking.

Electrical Hazards arise from the high accelerating voltage used to produce D-T fusion reactions in the sealed-tube source. Voltages as high as 200-kV may be present during normal operation. The source is designed such that the target and surrounding enclosure are operated at ground potential, and personnel are never exposed to high voltage during normal operation.

The control console, when accessed through the cabinet door at the back of the control rack, contains circuits with exposed 120 V wiring.

Chemical Hazards arise from the cooling-fluid and insulating gases used in the source and high-voltage power supply. These gases and fluids may also present a radiation hazard from induced radioactivity. The gases and fluids present are Vertrel XF, a Freon substitute used to cool the ion source; tap water for the target cooling loop, and SF_6 for insulating the HV power supply and neutron head. None of these substances are toxic in their normal state. The primary hazard is asphyxiation from air displacement if they are vented to the cave without adequate ventilation. However, high-voltage arcs may produce flourine gas as a breakdown product from SF_6.

Of all the hazards listed above, prompt and induced radiation are the most likely to be encountered during routine operation. Consequently, the bulk of this Hazard Control Plan concerns mitigating the effects of radiation produced by the neutron generator.

4. INITIAL RISK

There is a **MEDIUM** initial risk associated with the operation of the D-T generator. The equipment is built with two interlock inputs, which presume connection to some sort of barrier or access control system before the equipment can be operated. However, without analysis and review, arbitrarily chosen shielding or barriers may be ineffective or inadequate. Furthermore, simple connection of the interlocks to, say, microswitches on an access gate does not enforce a rigorous sweep and entry procedure. Therefore, without the shielding and access controls specified in this document, it is **PROBABLE** that an unintended exposure of personnel to radiation may occur, with moderate to severe health consequences.

5. INSTITUTIONAL REQUIREMENTS

Institutional requirements and guidance covering prompt radiation protection are described in LANL documents:

- LIR-402-700-01.0 "Occupational Radiation Protection Requirements" [3]
- LIR-402-700-01.0, Attachment I "Access Control" (Requirements) [4]
- LIG-402-700-01.0, Attachment I "Access Control" (Guidance) [5]

In particular, "Appendix 9B: Accelerator and Radiation-Producing Device (RPD) Access Control Requirements" is relevant to this HCP.

"Machine Neutron Generators" that contain tritium are also subject to the controls for accountable radioactive sealed sources as set forth in:

- LIR-402-716-01.1 "Radioactive Sealed Source Accountability/Control" (Requirements) [6]
- LIG-402-716-01.0 "Radioactive Sealed Source Accountability/Control" (Guidance) [7]

6. CONTROLS

6.1 Prompt Radiation Protection

The nominal output of the A-711 neutron generator is 10^{11} 14-MeV neutrons/sec. At a distance of 1 m, the flux is 8×10^5 n/cm^2/s and the dose rate is 22.4 Rad/hr (168 Rem/hr). This dose rate mandates the access controls specified in LIR402-700-01.0, Chapter 9, Table 2, Row 2, for Radiation Producing Devices [4].

As a point of comparison, the neutron flux on WNR Target-4 Flight path 30L at 20 m (near the boundary of the Target-4 exclusion area) is approximately 4.3×10^6 n/cm^2/s for all neutron energies above 1 MeV for a typical beam current of 5 microamps. This translates to a dose rate of about 700 Rem/hr.

The prompt radiation protection system consists of three layers:

1. concrete shield block walls and ceiling
2. steel/borated-polyethylene collimation crypt
3. barriers and Interlocks

The **walls and ceiling** of the cave are constructed from LANSCE standard shield blocks and constitute the primary control against prompt radiation from the source. A layout of the cave and experimental area is shown in Figure 1. The cave walls are constructed mostly of standard B3 shield blocks (6' w x 3' d x 10' h). One corner of the cave, near the former NTOF beam stop, consists of steel at least 3' or more in thickness. The cave roof is 3' thick in the front half and 2-1/2' thick in the rear half. See Figure 2 for a side profile and Figure 3 for a front profile.

The standard position of the source, as defined by its location in the collimation crypt, is 4' above the floor, 6' from either side wall, and 7' from the back wall. This is the position upon which all radiation dose estimates are based. If it becomes necessary to substantially reposition the source, the dose estimates must be recalculated and then reviewed and approved by the LANSCE-FM Radiation Protection Engineer. The standard position of the source (drawn to scale in Fig. 1) is defined by paint marks on the floor that outline the support legs of the collimation crypt. Conformance to this standard position will be confirmed in a startup checklist (Appendix C).

Dose rates are calculated with an assumed density of ρ = 2.4 g/cm^2 for concrete and a fast neutron attenuation length of λ = 12.5 cm. This density is consistent with the nominal volume (180 ft^3) and weight (13.5 ton) of a B3 shield block. The empirically determined attenuation length [8] is 1.5 times larger than that based on neutron total cross sections (8.4 cm), and thus contains a buildup factor of 1.5.

The primary shielding, consisting of the walls and roof as shown in Figs 1-3, is configured so that the radiation dose below the top of the walls (10 ft above ground level) will be less than 100 mRem/yr (2080 hr) if the source is operated with no additional shielding (i.e., outside the collimation crypt). On the roof the maximum expected dose rate is 56 mRem/hr directly above the unshielded source. Because this constitutes a Radiation Area (> 5 mRem/hr), the roof perimeter is enclosed with a chain-link fence that will be locked for access control.

The **Collimation Crypt** consists of a steel table and a cubical stack of steel blocks that surrounds the source on five sides. The outside surface of the stacked steel is encased in a minimum 1" thickness of 5% borated-poly for thermal neutron absorption. A drawing of the collimation crypt is shown in Figure 4. In the forward direction, neutrons must pass through a least 18" of steel before escaping. A set of removable collimation plates is used to define a conical beam in the forward direction. The angular width of the beam is 4.4 deg. This produces a 25" diameter beam spot on the downstream shield block outside the cave weather doors (27 ft from the source). When the source is operating at full intensity, the fast neutron dose rate within this beam spot is 2.5 Rem/hr at the point where it enters the wall.

The primary purpose of the collimation crypt is to produce a collimated fast neutron beam and thereby reduce background rates within the cave and protect equipment. As described above, the cave walls and roof provide adequate radiation protection even if the source is operated in its standard location without the additional shielding of the collimation crypt. However, there is one weakness in the configuration of the cave walls and roof: in the forward direction a direct line of sight exists between the source and the top of the downstream shield block (outside the weather doors). The radiation dose at this position (> 10' above ground level) would be 2.4 Rem/hr if the collimator plates were removed or the collimation crypt was not present. With the collimation plates in place the radiation dose rate will be reduced to below 1 mRem/hr at the top of the shield block. This assumes an attenuation length of 6.8 cm for 14-MeV neutrons through iron, which includes a build-up factor of 1.5.

Because of the POTENTIAL for creating a High Radiation Area on top of the shield blocks, a necessary condition for operation of the source is that the collimation plates must be in place. This will be confirmed in a startup checklist (Appendix C). If it becomes necessary to adjust the collimation plates to produce a beam larger than that specified above (25" diam at the downstream wall), then the change must be reviewed and approved by the LANSCE-FM Radiation Protection Engineer.

The final layer of protection against prompt radiation is the **barrier gate and interlocks** that prevent neutrons from being generated except under well defined conditions. A locked and interlocked gate is installed at the entrance maze to the neutron cave. Access through this gate is controlled by a Kirk-key and LANSCE-6 standard Experimental Personnel Access Control System (EPACS), which enforces a defined sweep-and-lockup procedure. The EPACS provides two ready signals to the interlocks built into the commercial equipment. These equipment interlocks are the "door" interlock input on the back of the control console in the control shed (53-1270) and the "pit" interlock on the system junction box on the cooling cart in the neutron cave. Both interlocks must be made up to initiate neutron production. Conversely, if either interlock is broken during neutron production, the accelerating high voltage will be turned off and neutron production will cease.

Detailed procedures for interlock testing and cave lockup and entry are contained in:

- APPENDIX A: NRAD EPACS Interlock Check Procedure
- APPENDIX B: NRAD Cave Sweep & Entry Procedure

The interlock test procedure must be performed every six months or after any maintenance work on the EPACS system.

6.2 Induced-Radiation Protection

Materials, equipment, and tools present in the cave during operation of the source may become activated and present a hazard if removed from the cave, or if personnel are exposed to these activated materials inside the cave.

To prevent the inadvertant release of radioactive material, all equipment or material present in the cave during operation of the source must be monitored and tagged by an RCT before removal to another area.

Other than objects placed directly in the collimated beam, the materials most likely to present a hazard to personnel from induced radioactivity are the cooling fluids (Vertrel XF and water), the insulating gas in the neutron head (SF_6), and the iron in the collimation crypt. Personnel entering the cave the first time following each operation of the source must be accompanied by an RCT. The RCT will make a survey to identify areas of high dose rate and may, depending on the survey results, require additional controls or permits before work can continue. This requirement will remain in effect until enough operating experience has been acquired to suggest alternate procedures. If this requirement is changed, then the basis for the change must be documented and this HCP amended accordingly.

The activation reactions of primary concern are the following:

- $^{16}O(n,2n)^{15}O$(2 min) (water)
- $^{19}F(n,2n)^{18}F$(1.8 hr) (SF_6, Vertrel XF)

- $^{32}S(n,p)^{32}P$(14.3 d) (SF_6)
- $^{56}Fe(n,p)^{56}Mn$(2.6 hr) (crypt)

The SF_6 in the neutron generator head will be shielded by the iron in the crypt. Sulfur activation is therefore not a concern except when the neutron head must be serviced. The iron crypt and circulating fluids will have half lives on the order of several hours or less. Exposure to induced radioactivity can therefore be minimized by waiting overnight before performing work or maintenance activity near the crypt or cooling cart.

6.3 Electrical protection

The high-voltage power supply and neutron head are designed such that the target and external surfaces run at ground potential. These units are sealed, insulated, and pressurized. During routine operation, personnel are not exposed to high voltage. It is important, however, to maintain a good ground on the HV supply. A cable must be connected from the ground stub on the front dome of the HV supply tank to one of the ground buses on the south or north walls of the cave. This will be confirmed in a startup checklist (Appendix C).

During maintenance operations it may become necessary to open the HV supply tank. Opening the tank will expose the capacitors contained inside. These capacitors must be discharged following the instructions in the operating manual, using equipment designed for this purpose. This HCP does not cover these hazards. The LANSCE-3 Electrical Safety Officer must be consulted before performing this work.

Plastic barriers have been installed to protect against inadvertant access to 120 V circuitry in the back of the control console. The cabinet door at the back of the control console and the plastic barriers must be posted with appropriate warning stickers. Any maintenance work on the console while it is energized must follow the requirements of LIR-402-600-01.1 "Electrical Safety" [9].

6.4 Chemical protection

The fluids and gases required for routine operation of the source are:

- tap water, for the target cooling loop,
- Vertrel XF, for the ion-source cooling loop,
- SF_6, for insulating the HV tank and neutron head,
- dry nitrogen, for flushing the HV tank and neutron head

None of these materials are toxic. The primary hazards are induced radioactivity from exposure to the neutron source, or asphyxiation from venting gas into a closed room without adequate ventilation. The HV tank contains approximately 10^3 liters (35 ft^3) of SF_6 at 33 psi. The neutron head contains approximately 22 liters (0.8 ft^3) of SF_6 at 60 psi. At room pressure, the total volume of gas in the HV tank and neutron head is approximately 110 ft^3. The volume of the cave is approximately 3120 ft^3. If all the SF_6 is released into the cave it will not displace enough air to be an asphyxiation hazard.

If high voltage sparking has occurred, the SF_6 may contain Flourine gas. If it becomes necessary to vent the HV tank or neutron head (e.g., for maintenance work), the weather doors to the cave should be opened and transfer lines should be attached to vent gas outside the cave.

If it becomes necessary to drain either cooling loop (e.g., for maintenance work), a spill kit, gloves, and eye protection must be on hand and RCT monitoring must precede all work. Sealable containers of adequate size to contain the drained fluids must be present before work begins. The water volume in the target cooling loop is approximately 3.5 Gal (13.4 liter) and the volume of Vertrel XF is approximately 0.5 Gal (2 liter). The bottom wall edges of the cave have been weather sealed to prevent outside water from leaking in. This sealing will also prevent spills from leaking out. If the entire volume of water and vertrel XF is spilled in the cave, it will cover the floor with a layer approximately 0.5 mm deep. This is well below the height of existing water barriers. In addition, a trench in the southeast corner of the cave is available for collecting spilled fluids.

6.5 Posting

Shield blocks, fences, gates, and barriers shall be posted in a manner that clearly specifies their purpose in order to avoid inadvertant configuration changes or challenges.

A radiation survey shall be conducted by ESH-1 the first time the neutron generator is operated. This survey will verify that radiation levels are within the limits estimated in this HCP. Radiological postings will be generated or adjusted based on the results of this survey. A new radiation survey and adjustment of radiological posting will be required after any change in the shield wall configuration, or increase in collimated beam size within the cave.

The entrance to the NRAD cave shall be posted as a "High Radiation Area when beam is on" and as a "Controlled Area for volume contamination and external radiation hazards". The "Controlled Area" posting means that only authorized personnel may enter the NRAD cave alone. An unauthorized person may enter the NRAD cave only if continuously escorted by an authorized person.

Exit posting requirements will be posted at the exit door. It is your responsibility to be aware and observe the requirements.

6.6 Facility Keys

Five keys control access to the NRAD facility and the operation of associated equipment. These are:

1. MPF-66 key
2. Controls shed (53-1270) door key
3. NRAD EPACS padlock key
4. Console Power key
5. Entrance Gate Emergency Access key

The MPF-66 Key is issued to LANSCE-3 group members and authorized visitors. It controls access to many areas at WNR. The NRAD cave weather doors are locked with an MPF-66 Key.

The Controls Shed key provides access to the Data and Controls Shed, 53-1270. Copies will be provided as needed to authorized NRAD experimenters. A copy will be stored in the LANSCE-3 key lock box.

The NRAD EPACS padlock key is used to control access to EPACS circuitry in the NRAD cave. This key is required for testing the EPACS system. It will be stored in the LANSCE-3 key lock box.

The Console Power key is used to energize the neutron generator control console in the Controls Shed, 53-1270. Neutrons cannot be generated without this key. This key will be stored in the LANSCE-3 key lock box during periods when the NRAD facility is not operating and not attended. This key will be checked out only to persons authorized by LANSCE-3 Line Management.

The Entrance Gate Emergency Access key is required if the EPACS system loses power while the area is secured. This is presently the same key used for emergency access to other EPACS and PSS areas at LANSCE. LANSCE-6 maintains custody of this key. Contact LANSCE-6 for assistance if this key is required.

6.7 Startup checklist

Before the system is started after being unattended for more than one day, a checklist will be completed to verify the integrity of all shield blocks, barriers, signs, fences, and posting. This checklist will include visual inspection of both interlock inputs and all cooling fluid lines. The checklist will also verify that no unrelated work is taking place on or near the tops of the shield block walls where a potential radiation hazard may exist. The detailed checklist is contained in:

- Appendix C: NRAD startup checklist

This checklist is intended to serve as a SAFETY checklist, and does not replace or supersede any equipment startup checklists outlined in the manufacturer's operating manual.

7. TRAINING AND AUTHORIZATION

Personnel operating the neutron generator or performing experiments in the NRAD facility must have current DOE Rad Worker Training and TA-53 site-specific training.

Authorization to perform work at the NRAD facility will be effective after reading this procedure and signing the NRAD HCP Log in the LANSCE-3 Group Office. Authorization will be valid for twelve (12) months, at which time this document must be reviewed again. This ensures that personnel will be aware of current hazards.

Only personnel authorized by LANSCE-3 Line Management may operate the neutron generator. This authorization will be documented as OJT (On the Job Training) in the EDS (Employee Development System).

8. DOSIMETRY

Both TLD and PN3 dosimetry are required.

9. WASTES

No wastes are generated in the routine operation of the source.

10. RESIDUAL RISK

Provided that the shielding, access controls, and RCT monitoring specified in this document are implemented and observed, the residual risk is **LOW**. That is, there is only a **SLIGHT** chance that an event will occur that results in moderate inadvertant radiation exposure or injury, or release of radioactive materials to the environment.

11. EMERGENCY PROCEDURES

In the event of a health or life-threatening emergency (injury, fire, etc), assess the situation and then call 911. Be prepared to state the location: TA-53-3N (NRAD Cave) or TA-53-1270 (Controls shed) and nature of the emergency.

If possible, turn off the Main Power key switch on the control console.

A fire alarm pull box is located on the south wall of the neutron cave.

Additional assistance may be obtained by calling:

- LANSCE CCR(7-5729),
- Health Physics (7-7069),
- LANSCE-3 Group Office (7-5377).

Notify LANSCE-3 Line Management as soon as practical.

12. CHANGE CONTROL

The original copy of this document will be maintained in the LANSCE-3 group office.

13. REFERENCES

1. MF Physics Corporation,
   5074 List Drive, Colorado Springs, CO 80919
   (http://www.mfphysics.com)
2. E.I. du Pont de Nemours and Company, Inc.,
   (http://www.dupont.com/vertrel/prod/index.html)
3. LIR-402-700-01.0 (Requirements):
   http://labreq.lanl.gov/pdfs/ops/lir/LIR40270001.pdf
4. LIR-402-700-01.0, Attachment I (Requirements):
   http://labreq.lanl.gov/pdfs/ops/lir/LIR40270001ATTI.pdf
5. LIG-402-700-01.0, Attachment I (Guidance):
   http://labreq.lanl.gov/pdfs/ops/lir/LIG402700ATTI.pdf
6. LIR-402-716-01.1 (Requirements):
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8. Ralph H. Thomas and Graham R. Stevenson,
   Radiological Safety Aspects of the operation of proton accelerators,
   IAEA, Vienna, 1988
   (http://www.iaea.or.at/worldatom/publications/nrs/rsa.html)
9. LIR-402-600-01.1 (Requirements):
   http://labreq.lanl.gov/pdfs/ops/lir/LIR40260001.pdf

14. ATTACHMENTS

- Figure 1. NRAD cave and experimental area layout
- Figure 2. NRAD cave side profile
- Figure 3. NRAD cave front profile

15. REVISION HISTORY

- 28 Jan 2002, (TNT) Initial version (.0)

LANSCE-3 HCP-19, Appendix A
NRAD CAVE INTERLOCK CHECK PROCEDURE

A.1 Purpose

This procedure tests for proper function of the circuits and warning devices in the Experimental Personnel Access Control System (EPACS) for the NRAD cave (53-3N) and its interface to the Neutron Generator Control Console in the NRAD controls shed (53-1270).

A.2 Responsibilities

LANSCE-3 has operational and Line-Management authority for activities in the NRAD cave. The EPACS equipment is designed, supplied, and maintained by LANSCE-6. Issues related to the maintenance of the EPACS equipment must be referred to LANSCE-6. LANSCE-3 is responsible for the safe operation and testing of the equipment.

The LANSCE-3 Instrument Responsible Staff Member (IRSM) for the NRAD cave shall:

1. Ensure that this procedure is completed as required.
2. Certify the review process by signing and dating the checklist.
3. Notify LANSCE-3 Line Management of any discrepancies discovered while executing this procedure.

A.3 General Considerations

1. The NRAD Cave EPACS is a stand-alone system not interfaced to the LANSCE Radiation Security System (RSS). The EPACS "A" and "B" outputs instead go to the Neutron Generator "Door Interlock" and "Pit Interlock", respectively.
2. NRAD Cave interlock checks are required
   a. every 6 months subject to scheduling constraints, and not to exceed 7 months, or
   b. if control of the EPACS has been relinquished (interlock or configuration control not maintained)
3. The control console for the neutron generator is located in the controls shed, building 53-1270.
4. Prior to beginning the interlock checks, the NRAD cave and controls shed shall be cleared of personnel not directly involved in the checks.

A.4 Prerequisites

1. Use of the NRAD EPACS Padlock Key in performance of this procedure is authorized. Properly sign out the key from the LANSCE-3 Key Locker when use is necessary.
2. An MPF-66 key is required for access through the NRAD cave weather doors.
3. This procedure shall be performed by two LANSCE-3 authorized individuals.
4. The NRAD cave must be in a safe condition before beginning this procedure.
5. The Neutron Generator Main Power key is required.
6. The Neutron Generator must be in an operational state.

A.5 Precautions

Depending on the time since the neutron generator was last operated, significant levels of induced radioactivity may be present near the collimation crypt and neutron generator coolant lines. Observe all radiological posting.

A.6 Procedure

1. The Interlock checks shall be performed in the exact sequential order shown on the checklist.
2. Each step of the checklist shall be initialed in the space provided **only** if the step is completed satisfactorily.
3. Any discrepancies with this procedure shall be brought to the attention of LANSCE-3 Line Management, who will determine if a procedural change is needed prior to continuing with this procedure.
4. Once contacted, LANSCE-3 Line Management, in consulation with the IRSM, shall determine if an error does exist.
    a. if it is determined that no error exists, the procedure may continue.
    b. If it is determined that the procedure is in error, the procedure shall be stopped and **NOT** continued.
5. Necessary corrections to the procedure shall be reviewed and approved by the LANSCE-3 Line Management.
6. Once the procedure has been corrected and approved, the associated checklist shall be **completely** redone.
7. Should any inoperative, faulty, or suspect interlocks or devices be discovered in the EPACS system during the course of this procedure, the LANSCE-6 Group Office shall be contacted prior to continuing with the procedure.
8. Once contacted, an RSS specialist designated by LANSCE-6 shall determine if a problem does exist.
    a. if it is determined that no problem exists, the procedure may continue.
    b. If it is determined that a problem does exist, the procedure shall be stopped and **NOT** continued.
9. If repairs are required, they shall be directed by the designated LANSCE-6 RSS specialist.
10. Once inoperative, faulty, or suspect interlocks or devices in the EPACS have been repaired, the associated checklist shall be **completely** redone.

A.7 Documentation

1. Successful completion of this procedure shall be recorded in the NRAD facility logbook.
2. Problems or discrepancies encountered when performing this procedure shall be noted in the NRAD facility logbook.
3. Completed, signed, and dated checklists shall be maintained in a binder in the NRAD controls shed.

A.8 References

1. None.

A.9 Attachments

1. EPACS Checklist for the NRAD Cave.

A.10 Revision History

1. 28 Jan 2002, (TNT) initial version (.0)

LANSCE-3 HCP-19, APPENDIX A.1
EPACS Checklist for the NRAD Cave.

Note: Personnel Required:

- Two LANSCE-3 authorized individuals are required to perform this procedure.
- These individuals will be referred to as P1 and P2 in the steps below.
- Individuals performing the procedure must be aware of their designation as it will determine their actions.

Note: Equipment Required:

Equipment should be held by P1 and P2 as follows:

- A timer or watch with 1 second resolution (both P1 and P2)
- NRAD EPACS Padlock key
- All NRAD cave Kirk keys (P1 and P2)
- MPF-66 key
- Neutron Generator Main Power key

Note: Zone Description:

There is a single zone, the area, protected by an EPACS with redundant safe strings ("A" and "B"). the area is comprised of the entrance maze and cave interior. There are two EPACS Scram/Siren/Resets (SSR) and one EPACS Exit Door Monitor (EDM).

- SSR01 is on the north interior wall of the cave.
- SSR02 is mounted on the shielding near the gate exit.
- EDM01 is mounted on the shielding next to the gate entrance.

Note: EPACS Control Panel:

- The EPACS Control Panel is located on the north side of the cave shielding near the gate entrance. It is mounted on the shield wall inside a weather-proof box.
- This panel is designated NRAD ECP 01.
- The panel has a logic display consisting of a ladder diagram with LEDs for the area on the front cover. This cover door may opened for access to the "A" and "B" Test Switches.

Note: Initial EPACS condition:

- Ensure that the NRAD the area is NOT secured.

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1. Verify that the NRAD Startup checklist (LANSCE-3 HCP-19 Appendix C) is complete and current with approved exceptions noted. (See NRAD Checklist Binder in 53-1270) ______

   Note: P1 and P2 proceed to the NRAD Cave the area entrance.

2. Verify that a current working copy of the NRAD Cave Sweep and Entry Procedure (LANSCE-3 HCP-19 appendix B) valid for seven (7) months is posted at the EPACS zone entrance. ______
3. Verify that the NRAD EPACS Padlock is installed and locked on the the area EPACS main box (NRAD ECP 01). ______
4. P2 enters the area and verifies the following:

NRAD SSR 01 on the north cave wall:

- Switch pulled out and illuminated ______
- Readily accessible ______

NRAD SSR 02 at the gate exit:

- Switch pulled out and illuminated ______
- Readily accessible ______

NRAD EDM 01 at the gate entrance (after closing gate)

- LOOP A illuminated ______
- LOOP B illuminated ______

Note: For the next step, P1 at NRAD ECP 01 records data, while P2 in the area area performs the checks. LPA, LPB and SCRAMS, BARRIERS & EXITS OK are on the ECP display panel. For each test, an initial means that the indications were:

- initially illuminated
- turned off when the test was conducted
- illuminated when the element being tested was returned to the original state.

5. P2 starts a sweep of the area by pressing the SWEEP SELECTION START push button on NRAD ECP 01. P2 retains the two Kirk keys and enters the area, closing the gate. P2 pushes in and then pulls out each SCRAM switch in the area, and then opens and closes the exit gate, one at a time.

   P1 records indications at NRAD ECP 01.

   NRAD SSR 01 on the north interior wall of the cave:

   - LPA ______
   - LPB ______
   - SCRAMS, BARRIERS & EXITS OK ______

   NRAD SSR 02 at the wall beside the exit gate:

   - LPA ______
   - LPB ______
   - SCRAMS, BARRIERS & EXITS OK ______

   NRAD EMN 01 next to the door entrance:

   - LPA ______
   - LPB ______
   - SCRAMS, BARRIERS & EXITS OK ______
6. P2 now restarts a sweep of the area by pressing the SWEEP SELECTION START push button on NRAD ECP 01. P2 retains the two Kirk keys and enters the area, closing the gate. P2 performs a sweep but stops before pressing the final reset inside the area.

   For the step below, P1 at NRAD ECP 01 observes indications and measures elapsed time from the moment the RESETS OK indicator is illuminated while P2 operates equipment.

P2 presses the last reset and exits the area.
P1 verifies that the RESETS OK and EXIT ENABLED indicators on NRAD ECP 01 illuminate.
P1 waits about one minute, verifies that the EXIT ENABLE indicator goes off, and records the elapsed time.

- RESETS OK illuminated ______
- EXIT ENABLED illuminated ______
- EXIT ENABLED goes off (after _____ seconds)

If the EXIT ENABLE remains illuminated for more than 90 seconds, then there is a system problem which must be corrected.

Note: For the next test, P2 is secured inside the area. P2 must carry the neutron generator main power key to prevent neutrons from being generated while this test is carried out.

7. P2 sweeps the area and remains inside after passing the Kirk keys to P1.
   P1 completes the sweep by capturing the master key in NRAD ECP 01 with P2 in the area.
   P1 verifies indications at NRAD ECP 01.
    - EPACS SECURED _____

   P2 now opens the gate from inside.

    - EPACS SECURED is *off* ______

   Note: For the remaining tests, the Neutron Generator Main Power switch must be turned on, and the cooling cart in the NRAD cave must be turned on. It may take as many as 20 minutes for all equipment interlocks (temperature and pressure) to become enabled. If necessary, enter the zone to turn on the cooling cart, then resweep and secure the zone in the next step.

8. P2 now returns keys and secures the area.
   P1 verifies indications at NRAD ECP 01.
    - LPA ILLUMINATED ______
    - LPB ILLUMINATED ______
    - EPACS SECURED ______

   Note: P2 now goes to the Neutron Generator Control Console (NGCC 01) in the controls shed (53-1270).
   P1 remains at NRAD ECP 01.

9. P2 verifies that the following indications are illuminated on NGCC 01:
    - "MAIN POWER ON" light is *on*. ______
    - "MAIN POWER DELAY" light is *on*. ______
    - "INTERLOCKS OK: ACCEL" is *on*______
    - "INTERLOCKS OK: ALL" is *on*______
    - "HIGH VOLTAGE CONTROL: OFF" is *on*. ______
10. P2 now pushes the "HIGH VOLTAGE CONTROL: ON" switch, with the High Voltage dial set to zero (0 V). The following light should now be illuminated on NGCC 01:
    - "HIGH VOLTAGE CONTROL: ON" is *on*. ______
11. P1 uses the NRAD EPACS Padlock key to open the outer door of NRAD ECP 01.
    P1 then presses and releases the DROP A switch.

P2 verifies interlock indications at the NGCC 01:

- "INTERLOCKS OK: ALL" is *off*. ______
- "HIGH VOLTAGE CONTROL: ON" is *off*. ______
- "HIGH VOLTAGE CONTROL: ON" cannot be turned on. _____

If the indication does not latch off but resets immediately on release of the DROP A switch there is a system problem which must be corrected.

12. P1 presses and releases the RESET A switch.
    P2 now pushes the "HIGH VOLTAGE CONTROL: ON" switch.
    P2 verifies interlock indications at NGCC 01.
    - "INTERLOCKS OK: ALL" is *on*. ______
    - "HIGH VOLTAGE CONTROL: ON" is *on*. ______
13. P1 now presses and releases the DROP B switch.
    P2 verifies interlock indications at NGCC 01.
    - "INTERLOCKS OK: ALL" is *off*. ______
    - "HIGH VOLTAGE CONTROL: ON" is *off*. ______
    - "HIGH VOLTAGE CONTROL: ON" cannot be turned on. _____

    If the indication does not latch off but resets immediately on release of the DROP B switch there is a system problem which must be corrected.

14. P1 presses and releases the RESET B switch.
    P2 now pushes the "HIGH VOLTAGE CONTROL: ON" switch.
    P2 verifies interlock indications at NGCC 01.
    - "INTERLOCKS OK: ALL" is *on*. ______
    - "HIGH VOLTAGE CONTROL: ON" is *on*. ______
15. P1 closes and locks NRAD ECP 01 using the NRAD EPACS Padlock key.
    - Exterior door handle latched. ______
    - NRAD EPACS Padlock attached and locked. ______

    P1 presses the SYSTEM FAULT reset push-button on the front of NRAD ECP 01 to clear all fault indications.

    - P1 observes "ACCESS ALLOWED" light on NRAD ECP 01 is *off*. ______
    - P1 verifies that the transfer key cannot be released. ______
16. P2 now presses the "HIGH VOLTAGE CONTROL: OFF" switch on NGCC 01.
    P1 releases the transfer key at NRAD ECP 01 to drop the EPACS.
    P2 verifies that:
    - "INTERLOCKS OK: ALL" is *off*. ______
    - "HIGH VOLTAGE CONTROL: ON" cannot be turned on. ______
17. Fill out the certification page by printing your name, entering your initials as they appear on the checklist, and the date

Performed by:	**Initials**	**Date**

Reviewed and approved by:

____

Date:

____

LANSCE-3 HCP-19, Appendix B:
NRAD CAVE EPACS SWEEP & ENTRY PROCEDURES

INDEX

A.0 SWEEP PROCEDURE

A.1 Purpose

This procedure is intended to ensure that the NRAD cave area is cleared of personnel prior to neutron beam operations.

A.2 Responsibilities

Sweep and lockup of the NRAD cave area may be performed by any qualified LANSCE-3 group member or NRAD experimenter. "Qualified" means that the person performing the sweep has received all required facility-specific ES&H training, understands the philosophy behind the EPACS, and has read this procedure. This procedure may also be performed by any PACS/RSS-qualified personnel from LANSCE-6 or ESH-1.

A.3 General Considerations

1. The control console for the neutron generator is located in the data/controls shed, building 53-1270.
2. The NRAD EPACS area consists of a single zone, comprised of an interlocked gate and entrance maze and an experiment cave protected by lockable but not interlocked weather doors. A LANSCE-3 MPF-66 key may be required to open the cave weather doors. There is one EPACS Scram/Siren/Reset(NRAD SSR 01) inside the cave on the north wall, and one on the wall inside the maze entrance gate (NRAD SSR 02). There is a single EPACS Control Panel (ECP) with LEDs that indicate EPACS status. The NRAD EPACS area must be secure to initiate neutron production.
3. ESH-1 may set the ADMIN KEY to control access for radiological control.
4. If all door Kirk keys are returned to the key bank, the Kirk master transfer key should be captured in the ECP to prevent loss.

A.4 Prerequisites

None.

A.5 Precautions

High levels of induced radioactivity may be present near the neutron collimation crypt and coolant lines immediately following neutron generator operation. Observe all radiological postings.

A.6 Instructions

1. Check the SYSTEM FAULT status at the EPACS Control Panel (ECP) (NRAD ECP 01) at the entrance gate. If a SYSTEM FAULT is latched, then reset the fault.
2. Make the following local announcement twice, prior to starting the sweep: "Personnel safety sweep of the NRAD cave now in progress. All personnel leave the NRAD cave."
3. Take control of the two NRAD Kirk keys.
4. On the NRAD ECP:
    a. Press the SWEEP SELECTION START button to set SWEEP IN PROGRESS. This sounds the horns.
    b. Check the SCRAMS & BARRIERS OK indication. If illuminated then all SCRAMS are pulled and all barriers are closed. If not illuminated, then a careful check of SCRAMS and barriers will be required.
5. **If SCRAMS & BARRIERS OK indication was NOT illuminated**, then carefully check all SCRAMS and barriers. (Ensure that SCRAM switch is illuminated and pulled and that barriers are closed and latched so the the Door/Exit Monitor LOOP A/B IN indications are illuminated)
6. Close the gate behind you, enter the cave, and proceed to the first reset. The READY indication on the first reset should be illuminated. If not, return to step 4 and correct the problem.
7. Press the first reset.
8. Sweep the cave. **Ensure no one is left inside the area by performing a careful visual check above, below, and behind all equipment, in alcoves, corners, etc.** As the sweep is conducted, verify that all SCRAM switches are readily accessible.
9. Exit the cave and close the weather doors. Proceed to the exit gate.
10. Press the second reset.
11. Exit the entrance maze and close the gate behind you, ensuring that it is fully closed.
12. Return all of the door Kirk keys to the transfer block and capture the Master transfer key in the ECP. This sounds the horns and starts the ~30 sec final horn time-out to zone secured.
13. After ~30 sec, verify that the EPACS is secured by observing the status lights at the ECP and the NRAD cave status sign.

A.7 Documentation

None.

A.8 References

None.

A.9 Attachments

None.

A.10 Revision History

1. 28 Jan 2002, (TNT) Initial version

LANSCE-3 HCP-19, Appendix B:
NRAD CAVE EPACS SWEEP & ENTRY PROCEDURES

INDEX

B.0 ENTRY PROCEDURE

B.1 Purpose

This procedure is intended to facilitate routine access to the NRAD cave during neutron-generator operating periods.

B.2 Responsibilities

Entry into the NRAD cave may be performed by any qualified LANSCE-3 group member or NRAD experimenter. "Qualified" means that the person performing the sweep has received all required facility-specific ES&H training, understands the philosophy behind the EPACS, and has read this procedure. This procedure may also be performed by any PACS/RSS-qualified personnel from LANSCE-6 or ESH-1.

B.3 General Considerations

1. The control console for the neutron generator is located in the data/controls shed, building 53-1270.
2. The NRAD EPACS area consists of a single zone, comprised of an interlocked gate and entrance maze and an experiment cave protected by lockable but not interlocked weather doors. A LANSCE-3 MPF-66 key may be required to open the cave weather doors. There is a single EPACS Control Panel (ECP) with LEDs that indicate EPACS status. The neutron-generator high voltage must be off to obtain ACCESS ALLOWED status (BEAM OFF).
3. ESH-1 may set the ADMIN KEY to control access for radiological control.
4. If all door Kirk keys are returned to the key bank, the Kirk master transfer key should be captured in the ECP to prevent loss.

B.4 Prerequisites

None.

B.5 Precautions

High levels of induced radioactivity may be present near the neutron collimation crypt and coolant lines immediately following neutron generator operation. Observe all radiological postings.

B.6 Instructions

1. Ensure that high-voltage to the neutron generator has been shut off at the control console

in the controls shed.

2. If the ADMIN KEY is set, contact ESH-1 for entry.
3. Ensure the ACCESS ALLOWED LED is lit on the ECP.
4. Push the key release button on the ECP. This will drop the zone EPACS and allow the Kirk master transfer key to be released.
5. Use the Kirk master transfer key to release the door Kirk keys. Each individual entering the cave must take a door Kirk key or be accompanied by an individual in possession of a door Kirk key.
6. Open the entry/exit gate, and enter.

B.7 Documentation

None.

B.8 References

None.

B.9 Attachments

None.

B.10 Revision History

1. 28 Jan 2002, (TNT) Initial version

LANSCE-3 HCP-19, Appendix C:
NRAD STARTUP CHECKLIST

ITEM	VERIFIED
No work on roof or walls	_Y_ / _N_
Roof fence locked	_Y_ / _N_
Shield walls and hand-stack intact (cf. Fig 1.)	_Y_ / _N_
Back-wall-penetration shielding in place	_Y_ / _N_
Collimator crypt intact and positioned (cf. Fig. 1 and paint marks on floor)	_Y_ / _N_
Collimator plates inserted (cf. Fig. 4)	_Y_ / _N_
HV ground cable connected	_Y_ / _N_
Water cooling lines intact, no leaks	_Y_ / _N_
Vertrel cooling lines intact, no leaks	_Y_ / _N_
"Pit interlock" connected (cooling cart)	_Y_ / _N_
"Door Interlock" connected (console)	_Y_ / _N_

Checked by:	**Date:**

HAZARD CONTROL PLAN for D-T NEUTRON GENERATOR OPERATION IN THE NRAD CAVE (53-3N)

Authorized Users

By signing below, I acknowledge that I have read LANSCE-3 HCP-19 (HAZARD CONTROL PLAN for D-T NEUTRON GENERATOR OPERATION IN THE NRAD CAVE (53-3N)) and have satisfied all training requirements.

NAME (print)	GROUP	INITIALS	DATE

Neutron Radiography (NRAD) facility

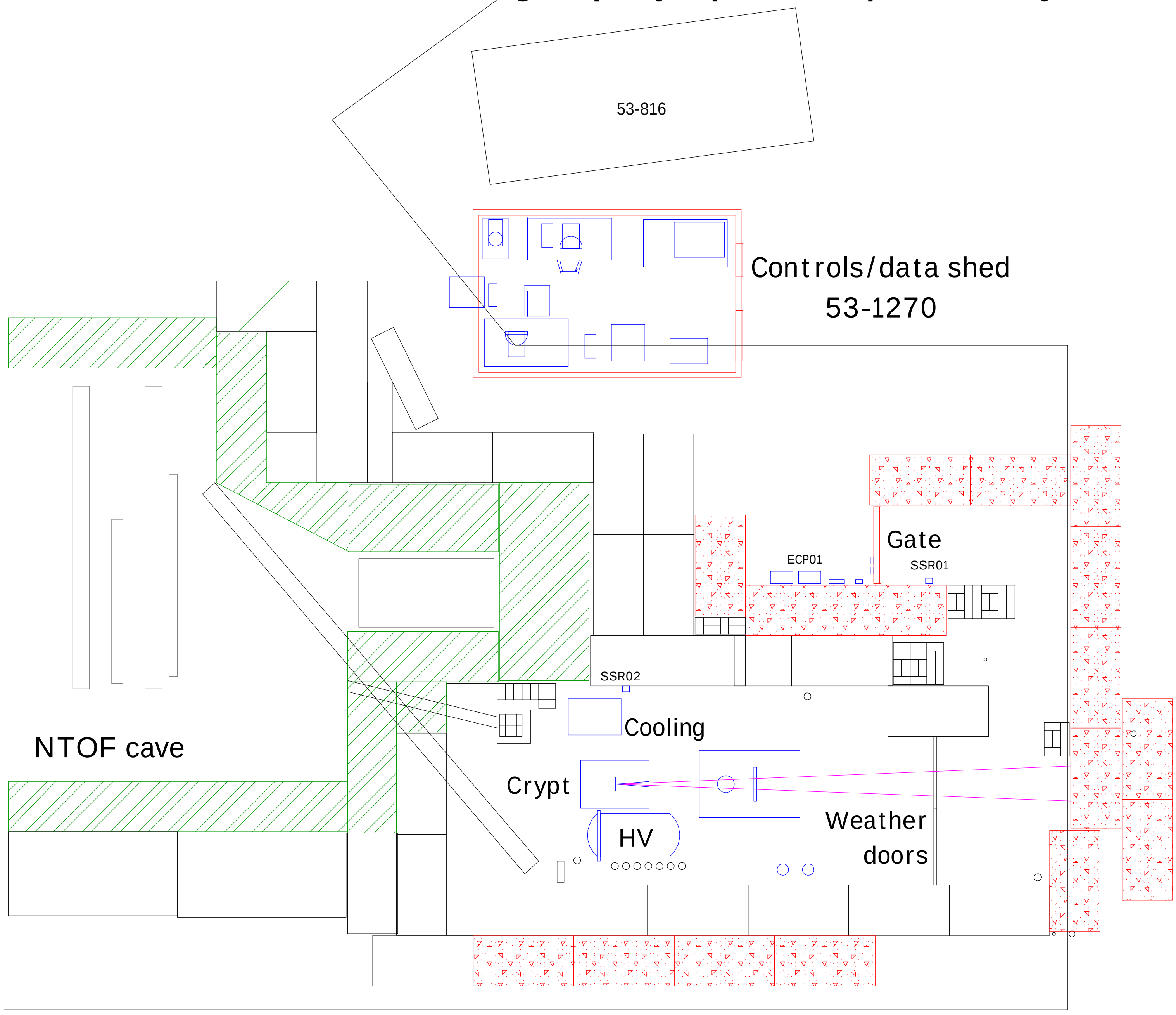
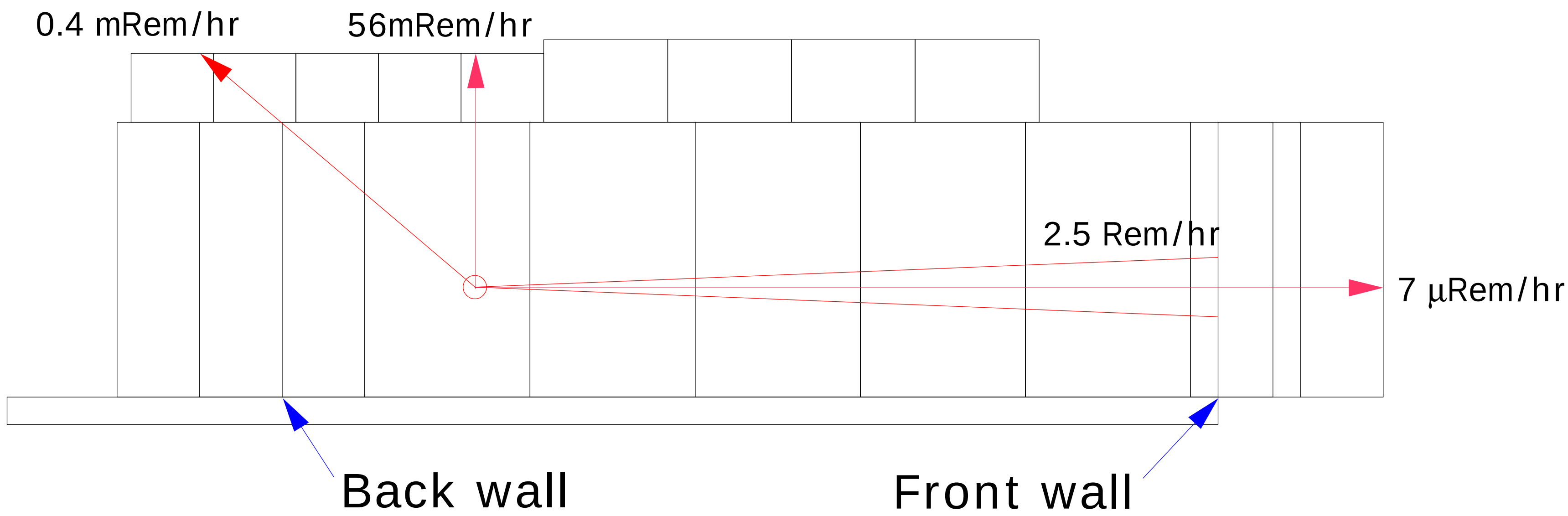


Figure 1.

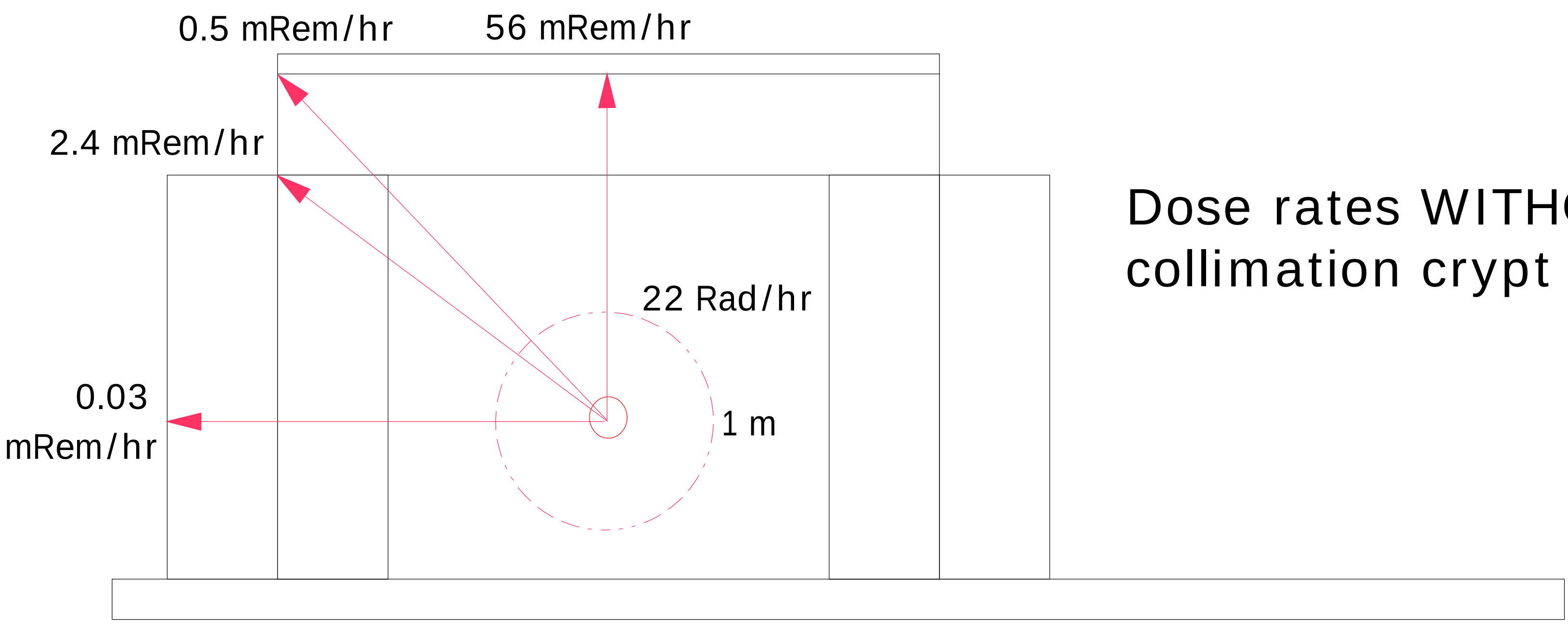
Neutron Radiography (NRAD) cave
(side section)



Assumptions:
14-MeV neutrons, λ = 12.5 cm, ρ = 2.4 g/cm^2

Figure 2.

Neutron Radiography (NRAD) cave (front section)



Dose rates WITHOUT collimation crypt

Assumptions:
14-MeV neutrons, λ = 12.5 cm, ρ = 2.4 g/cm^2

Figure 3.

D-T Generator Collimation Crypt

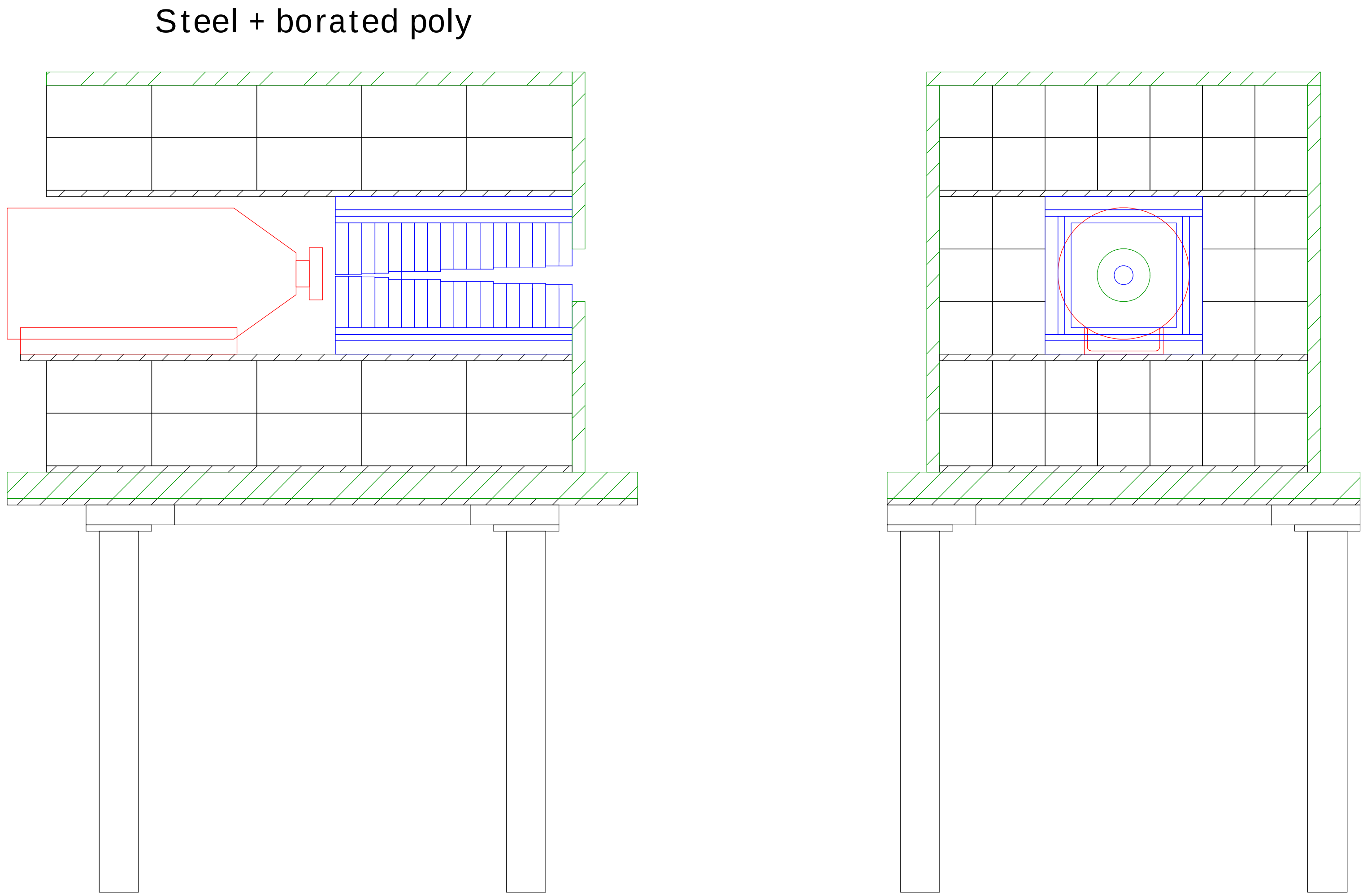


Figure 4.